A Realistic Cosmological Model Based on Observations and Some Theory Developed over the Last 90 Years

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ABSTRACT

<u>Introduction</u>

This meeting is entitled "A Century of Cosmology." But most of the papers being given here are based on work done very recently and there is really no attempt being made to critically review what has taken place in the last 90 or 100 years Instead, in general the participants accept without question that cosmology equates to "hot big bang cosmology" with all of its bells and whistles. All of the theory and the results obtained from observations are interpreted on the assumption that this extremely popular model is the correct one, and observers feel that they have to interpret its results in terms of what this theory allows. No one is attempting to seriously test the model with a view to accepting it or ruling it out. They are aware, as are the theorists, that there are enough free parameters available to fix up almost any model of the type.

The current scheme given in detail for example by Spergel et al (2006, 2007) demonstrates this. How we got to this stage is never discussed, and little or no attention is paid to the observations obtained since the 1960s on activity in the centers of galaxies and what they imply. We shall show that they are an integral part of a realistic cosmological model.

In this paper I shall take a different approach, showing first how cosmological ideas have developed over the last 90 years and where mistakes have been made. I shall conclude with a realistic model in which all of the observational material is included, and compare it with the popular model. Not surprisingly I shall show that there remain many unsolved problems, and previously unexpected observations, most of which are ignored or neglected by current observers and theorists, who believe that the hot big bang model must be correct.

<u>The Beginning: 1915-1936</u>

The major starting point was Einstein's development of general relativity. In applying his gravitation theory to the universe as it was then know (the Milky Way) he tried to explain a static universe. He could only do this by introducing the cosmical constant. This was Mistake 1 made by a great theorist who was misled, because no one realized how large and

complex the universe was, and the astronomical community barring a few notable exceptions like Heber Curtis all believed that everything was contained within the static Milky Way.

In 1922 and 1927 Friedmann and Lemaitre independently showed that Einstein's equations allow both expanding and contracting solutions. This work came at about the time Hubble and others using the spectra of spiral nebulae obtained by Besto Slipher at the Flagstaff Observatory showed that there was a good correlation between the redshifts and the apparent magnitudes of the nebulae (the fainter nebulae, the larger were the redshifts). It already had been shown by Hubble in 1924 that the spiral nebulae (galaxies) lie outside our Milky Way and are independent "island universes".

Overwhelmingly, the majority concluded that the redshifts must be due to expansion. This could have been wrong, as was suggested by Fritz Zwicky, Edwin MacMillan, Max Born, and others, but this view (the tired light hypothesis) goes against atomic physics and is generally neglected.

Since the observed expansion and the Friedmann solutions to Einstein's equations came at about the same time, by about 1930, it was generally accepted that the universe must be expanding. Thus, if energy is conserved, this means that extrapolation back in time forces us to the conclusion that early in its history, the universe was very small and compact.

At that time nuclear physics was in its infancy so that no realistic discussion of the nuclear physics of an early universe could be made. This is seen from the work in 1936 by Lemaitre in his paper entitled, "The Primeval Atom," and also by studies by Houtermans and Atkinson. However, by the late 1930s experimental nuclear physics involving the lightest isotopes had seen dramatic progress, and by 1938 Hans Bethe, C.F. Weitzacker, Charles Crichfield and others had shown that at high temperatures and densities in the centers of stars, neutrons, protons, electrons and positrons, neutrinos, and radiation will interact through a series of reactions so hydrogen can be burned to produce helium, the next most abundant nucleus to hydrogen in the periodic table. Thus it was possible that helium could be produced in an early universe. But in thinking along those lines George Gamow and others were already unconsciously rejecting another possibility. This was the possibility that while the universe is expanding, it always remains the same. If this was correct, the universe never had a young, dense phase.

Nearly twenty more years were to pass before T. Gold seriously made this proposal in 1947-1948. He made it to Hermann Bondi and Fred Hoyle. They worked out the consequences of this idea, and the three of them published two papers on the steady-state cosmology (Bondi & Gold, 1948; Hoyle 1948). This turned out to be a very unpopular theory. it requires that creation takes place not in an instant at a beginning, but throughout

the cosmos, at a steady rate determined by the rate of expansion (i.e. in modern terms it requires dark energy).

In this case the universe will not decelerate, as must be the case for the Friedmann models, but as energy is added it can maintain a steady expansion or even accelerate. In field theoretical terms this theory requires the existence of negative energy fields, which in the 1940's was the kind of physics not considered acceptable by the theoretical physics establishment. This is one of the reasons why the Hoyle-Narlikar C field theory of the 1960s (Hoyle & Narlikar, 1964) was so widely ignored. But now following the reports that the universe is accelerating, this type of creation (the so-called dark energy) has found acceptance. Today's phantom fields are recognized to be the C field of Hoyle and Narlikar in a different garb.

The neglect of this alternative, and the hostile approach taken to those who proposed the steady-state model was <u>Mistake 2</u>. However, it is fair to point out that while many of the observational objections to the steady-state turned out to be wrong, (cf Hoyle 1969), ultimately it was shown that the universe is evolving. Thus the simple steady-state model can be ruled out.

<u>The 1940's</u>

The next major step came with attempts to understand the origin of the chemical elements. Measurements of the relative abundances of the elements in the periodic table in meteorites and in the sun suggested that some of the gross features of the abundance curve were related to the nuclear structure of the nuclei. But first it was important to understand where the most abundant element after hydrogen - namely helium - had been made.

In the late 1940's many leading physicists, including George Gamow, Edward Teller, Enrico Fermi, Maria Mayer, Rudolph Peierls, and others, took the position that the most likely place of origin of the elements must be a place where there is likely to be a large baryon density, out of which the heavier elements could be built up from protons, neutrons, electrons, positrons, neutrinos, and radiation. The speculated that this must have been the early universe. While it was known that helium was being synthesized in stars, there was far too much of it for it to have been simply been built up in stars over the age of the universe. If we live in a Friedmann universe the time available is $\approx (H_o)^{-1}$ where H_o is the Hubble constant. At that time Hubble and Humason had given a value of $H_o of 550 km sec^{-1} Mpc^{-1}$, corresponding to an age of only about $2x10^9$ years. This was nothing like enough time, though Gamow and his colleagues did not know that over the next 40 years the value of H_o would be decreased by a factor ≈ 10 giving an age ≈ 15 Gyr. Even then this does not give enough time for helium production.

But in order to make nucleosynthesis in an early universe work at all, George Gamow and Alpher and Herman (cf Gamow 1946; Alpher & Herman, 1950) found that the had to <u>choose</u> a value for the initial baryon/photon ratio in the "beginning," a value radically different from what had been assumed before. It turns out that photons must dominated over baryons by a very large factor $\approx 10^{11}$ in such an initial synthesis scenario. Earlier it had been assumed that the baryons dominated over the photons. (The value that Gamow et al chose, is very close to the value used today.

Even when this was done, it was shown that only $^2D,^3He,^4He and some ^7Li$ could be built, since there is no stable mass 5 or 8. Having found this, most of the people working in this area left it, since it was clear that even if there was a hot big bang, only the most abundant element, helium, and the very light isotopes could have been made in it.

However, by then Gamow, Alpher and Herman and others were really attracted to the idea of a beginning, and a hot fireball of radiation, even though there was no proper theoretical basis for believing in it. Gamow et al predicted that as it expanded the hot fireball would maintain its Planckian form. Thus they predicted that if the radiation from the hot fireball was found it would have a black body form.

If such a situation ever did exist it is possible to calculate in detail the relative abundances of the light isotopes, particularly deuterium, and compare the results with observation.

In modern times there have been detailed calculations of the relative abundances of the light isotopes which will be made, and they have been compared with measured abundances, particularly of ^2D which can be detected in the spectra of QSOs with high redshifts. It is very difficult to make such measurements and it is a tour-de-force to achieve this, as Tytler et al (2006) have done better than almost any one else. It is often claimed therefore, that the abundances calculated originally by Gamow and his collaborators, and later by many others agree so well with the observed abundances, that this is proof that the big bang occurred. But this is simply not correct. The statement that the big bang theory <u>explains</u> the observed microwave background and also <u>explains</u> the helium abundances is to distort the meaning of words.

Explanations in science are normally to be considered like theorems in mathematics, to flow deductively from axioms and not to be restatements of axioms themselves.

Thus the radiation-dominated early universe is an axiom of big bang cosmology, and the supposed explanation of the CMB, and the light element abundances, is a restatement of that axiom. To reiterate, the baryon density and temperature relation has to be fixed suitably in order to explain the light element abundances.

Thus it must be remembered that the whole argument is based on the idea that helium was made by such a fireball, and much as most people want to believe it there is no independent evidence that this ever did take place. The blindness of the community to this point is Mistake 3.

What about the origin of all of the elements? Most of them cannot have been made in a big bang even if there was one.

The answer came from Fred Hoyle. In 1946, having noticed that the observed abundance curve showed a mild peak in the vicinity of iron - the region where nuclei are most strongly bound where the packing fraction is largest, he concluded that the heavy elements must have been made in some kind of equilibrium process when the mix must have reached a temperature $\approx 3x10^9$ (Hoyle 1946). He concluded that this must have taken place in stars. Thus the theory of stellar nucleosynthesis was born.

Hoyle followed this up with a more detailed study in 1954 (Hoyle 1954), and this in turn led to the extensive investigations of stellar nucleosynthesis by B^2FH and Cameron in 1957 in which the case was made and largely established that ll of the isotopes (with the exception of $^2D,^3He,^4He, and^7Li$ were made at different stages of stellar evolution. By then a great deal of observational evidence had been found showing that individual stars could be observed to be the synthesizing element. For example, the discovery of ^{43}Tc by Merrill. Clearly different properties of nucleosynthesis go on at different stages in the evolution of stars.

The 1950's Onward

What is clear from this is the very large amount of energy that must have been released in the production of helium from hydrogen, and that this must still exist somewhere in the universe.

In the 1940s cosmologists had no idea where such energy could be, but in retrospect we can also see now, that the most likely scenario is that it is contained in the cosmic microwave background. Back in 1926 Eddington had tried to estimate the amount of energy present in starlight in our galaxy, and in recent time this has been re-calculated by Pecker and Narlikar (2007).

The first indirect measurements of the microwave background radiation came in the late 1930's following the detection of absorption by interstellar molecules due to CH, CN, and CH^+ by Adams at Mount Wilson and McKellar at the Dominion Astrophysical Observatory. From purely observational considerations McKellar (1941) showed that the temperature of this radiation (if it is in black body form) lies in the range $1.8^oK < T < 3.46oK$. In view of

the later work this was a remarkably accurate estimate.

In the 1950s and 1960s a new generation of physicists and astronomers attempted to determine what is the correct cosmology. Ever since the 1930s most physical scientists, theologians, and philosophers have wanted to believe that we live in an evolving universe which had a beginning. In my view this all began because the discovery of the expansion was made in the same period when the Friedmann-Lemaitre solutions of Einstein's equations were found.

What actually happened?

In the late 1950's - early 1960's, Robert Dicke at Princeton became interested enough in Gamow, Alpher and Herman's ideas to try to detect the radation which the hot big bang believers had predicted would be present. The temperature could not be predicted, essentially because there is no basic theory for the big bang (cf Turner 1993), but it was believed that if the radiation was detected and had black body form this would prove that the big bang picture was correct.

Similarly the Russian cosmologists, led originally by Zeldovich believed passionately in this idea. This is clear from the fact that in Moscow, before the CMB was identified observationally, the Russian school referred to it as "relict radiation."

From that time on one huge danger that has been present and that continues to be be present is that all of the work on the CMB has been carried on by observers who are absolutely convinced that whatever they find, they are quite sure where it came from. This has led to a band wagon now so overwhelming that alternative interpretations of the data are hardly ever mentioned, never taught, or discussed at meetings, or referred to in textbooks.

What actually happened? In 1965 Penzias and Wilson found the CMB (Penzias & Wilson 1965), and by 1992 it had been shown to have a black body temperature of 2.728^oK (Mather et al 1990, 1994), right in the middle of the range given by McKellar (1941), though he was never given any credit for this, and most cosmologists have never heard of his name.

<u>If</u> it was generated in a big bang, then as Gamow and his colleagues proposed, it should have a black body spectrum. And of course the results obtained in space, most recently in the famous WMap observations, show the blackbody nature is well established.

But this is not in any sense proof that a big bang ever took place. Provided that the CMB is universal, and not contained to our own Milky Way, a big bang, <u>or any other process</u> which is able to provide the energy in black body form is acceptable.

There are two lines of argument which suggest that the CMB is universal. It has been

shown that a very small temperature asymmetry in the CMB is most likely due to the fact that our Milky Way is moving through the CMB with a velocity $\approx 500 km sec^{-1}$. Secondly, it was shown many years ago by Greisen, Zatzepin and Kusmin, that if the CMB is universal, at the highest energies, around $10^{19.5} ev$, the cosmic ray proton spectrum should be truncated, due to collisions between very high energy protons and photons of the CMB. This effect (the GKK effect)(a knee or at least a flattening in the spectrum) has recently been detected. Thus the truly extragalacatic nature of the CMB has been established.

In B^2FH we omitted any discussion of the origin of helium, though we were well aware of the problem. In 1955 Bondi, Gold, and Hoyle (1953) still believing in the simple steady state cosmology, proposed that the energy must have been emitted from K giant stars, and in 1958, not being aware of that work, I looked at possible places of origin of the helium(Burbidge 1958) and concluded that, the time scale for production of helium from hydrogen burning in stars was still too short, even if the universe had a beginning some 10 billion years ago.

Thus I concluded either that it had been made in a big bang, or it may have been made in short periods in the evolution of galaxies when they become much more luminous than they are for most of their radiating lives.

But what both Bondi et al, and I, paid little attention to, was the significance of the value of the energy density that must be present. Neither of us paid attention to the fact that this value, $4.5 X 10^{-13} erg cm^3$, which is derived simply by using the observed values of the mass density in galaxies and the observed He/H ratio, leads directly to the conclusion that if all of the energy released in the conversion of hydrogen to helium is still present, and has been degraded to black body form, the temperature will be about $2.75^o K$, which we know now <u>is</u> almost exactly the temperature of the universal CMB. In my view this cannot be a coincidence and is the key to our understanding. Overlooking this was <u>Mistake 4</u>.

It strongly suggests that the CMB does arise from hydrogen burning, but the time scale for the universe must be much longer than (H_o^{-1}). Since the universe is largely made up of condensed regions of matter (lumps) in the form of galaxies, these must be the places where the creation processes occur.

This leads us directly to the idea that the CMB arises in active galaxies, and the overall time scale leads us to the conclusion that the universe is cyclic. This means that we are in an expanding phase now, with a cycle time of ≈ 20 Gyrs. Later on the universe will slow down and start to collapse. However, the pressure exerted by the active galaxies as they squeeze close together means that the universe will not collapse back down to a region of extreme conditions.

By the time the galaxies begin to overlap the activity in the centers will generate enough

energy and pressure so that the collapse will slow down, and then begin to expand again, thus giving rise to a new cycle. The overall timescale must be $> 10^{12}$ years.

Since the 1960's it has become clear that the nuclei of galaxies can be extremely active. Thus it is natural to believe that they make up the discrete sources where little big bangs occur[1] The realistic model that this chain of evidence leads to drives us to the conclusion that creation must be taking place, but it occurs in the nuclear regions of galaxies, near massive centers which my be black holes. It is at the level that "new" physics, almost certainly involving a breakdown of Einstein's theory in the strong field limit, is required.

The model does not require that there was a unique beginning, i.e. no big bang.

The scenario that so many believe in today with a single beginning requires a series of ideas for which there is little or no, evidence. Those who believe in the model are driven by the over-riding (correct) belief that without a series of extra hypotheses that their model won't work. The hypotheses that are required, include an inflationary phase, (for which there is no independent evidence), initial density fluctuations (some believe of quantum origin, but no one knows), a non-baryonic matter which dominates over normal matter (for which there is no evidence), but without which galaxies cannot be formed, an absolute belief that all close interacting galaxies are coming together and never coming apart, etc. With all of these assumptions in place, strong claims are made that together with the CMB everything can be understood. But their model required that less than 5is baryonic!

Active Galaxies as the Most Likely Sites of Creation

Energetics

It was the discovery that powerful non-thermal radio sources often originate in apparently normal elliptical galaxies, and that some spiral galaxies show evidence of non-thermal optical energy in their nuclei (Seyfert galaxies) that led to the idea that centers of galaxies can literally explode and led to the idea of active galactic nuclei (AGN); an early review was published in 1963 by Burbidge, Burbidge and Sandage (1963).

Calculations of the amount of energy seen as a result of these nuclear events led to the conclusion that non-thermal energy in the range $10^{55} - 10^{60}$ ergs or $\approx 10 - 10^6 M\odot c^2$ was released in times $\approx 10^6 - 10^8$ years.

It was already clear in the 1960s that energies of this magnitude could, in principle, arise only from gravitational energy release due to matter falling on to a massive central black

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[1] It is of some interest to point out that all of the other less energetic diffuse radiation fields-radio, infrared, optical and X-ray-are believed to arise from large numbers of discrete sources.

hole, or they must be due to the creation process (Hoyle, Fowler, Burbidge & Burbidge, 1964). From the earliest days, the community embraced the view that the gravitational collapse mechanism must be the correct one. They relied heavily on leading theorists, particularly Martin Rees and Roger Blandford who made elegant models to explain these events - particularly the radio sources, using conventional physics.

This approach was to be expected since the release of gravitational energy is a process based on known physical theory, whereas invoking creation for which there is no well-developed theory is not a view that most scientists wish to take. This follows the prevailing view, that observed astronomical phenomena must be explained using known physics, and never the other way around, that from observations we can learn new physics. This despite the fact that observations often have led to the development of new physical theory, as was the case with Newton and others who succeeded him. I believe that her another major mistake (Mistake Number 5) is being made.

In this case my reasons are as follows: Unless the distance scale for the galaxies is completely wrong, we cannot escape from the view that what we see in the active objects is the generation of very large fluxes of relativistic particles and/or very large fluxes of photons with energies ranging all the way from radio to X-ray frequencies with a spectrum with a non-thermal index. In some cases the photon flux is seen to be variable in time meaning that the largest volume out of which the energy is generated must be as small as $10^{15} - 10^{16} cm$, and in the largest sources–the powerful radio galaxies, the sizes can range up to $\approx 10^5 kpc$, or $10^{23} cm$.

But if the ultimate energy source is associated with a massive black hole, classical theory tells us that energy can only be released very close to the Schwarzchild radius, as gravitational radiation, and the maximum efficiency obtained for a rotating black hole (the Kerr solution) is only about 8%. This energy has to be transformed and got out to very much larger regions where it can be detected either as photons, rapidly moving ejected gas, or large fluxes of relativistic particles which give rise to synchrotron radiation. The processes of energy transfer to different forms, and to much larger regions, are bound to be highly inefficient.

This view was brought home to me more than fifty years ago at the Solvy conference of 1956 where I described the very large energetics of the radio galaxies. The leading physicists immediately asked me whether I had any idea of the efficiency with which we can produce beams of relativistic particles on the Earth, i.e. in accelerators. With aid of Emilio Segre, one of my interrogators, I found that the efficiency of a linear accelerator (at Stanford) was about 1% and for a proton synchrotron, the efficiency is about $0.1 - 0.01\%$, i.e. the ratio of energy out (beam) to energy in (the power station) lies in the range $1 - ^{-2} - 10^{-4}$.

Independently Richard Feynman also pointed out to me that in making a proper calculation of the efficiency of such a machine (he liked to call M87 the M87 Synchrotron) account must be taken of the energy required to <u>build</u> the machine.

I have wrestled with this problem of efficiency ever since. I don't have a solution, but I believe that since the efficiency must be very low, the common view that we are just seeing matter falling into a massive black hole is fallacious.

If it were true, not only must the masses in the centers of galaxies be many orders of magnitudes greater than any detected so far, but where is all of the energy which is not seen? If the efficiency is 10^{-3} where is the 999/1000 of the energy which was released? This view is supported to a considerable extent by the detailed studies of the physics of the jet in M87 (Sunyaev et al 2005) which contains a massive black hole $\approx 10^8 M\odot$ and where the efficiency calculated from the non-thermal jet emission $\approx 10^{-3}$.

We do have direct evidence from dynamical studies that many nearby quiescent galaxies have central dark masses (black holes) with masses $0^6 - 10^7 M\odot$. For the majority of galaxies we cannot get a direct measurement of the mass in the nuclear region. However, a correlation has been found between the luminosity (assumed to be concentrated in the nucleus) and the masses of the nuclei of a few nearby AGN. Here the mass has been determined using the virial theorem using velocities of the rapidly moving gas (it is suspect in many cases since there is no evidence that the virial holds).

However using the correlation between luminosity and mass allows astronomers to estimate masses of high redshift systems. In all of these estimates they assume an efficiency of conversion of gravitational energy to luminosity $\approx 10\%$-very close to the Kerr limit.

We are then told that very distant, very luminous galaxies have masses of $10^{12} - 10^{13} M\odot$. But of course, if the redshifts of these objects are measures of distance, and to a very much lower efficiency is accepted, the masses would have to be $10^{14} - 10^{15} M\odot$ and any conventional scheme for making galaxies fails.

Thus I believe that creation in the galactic nuclei in situations in which Planck particles are produced and the Hoyle-Narlikar creation process is at work is much more likely. In the creation process the efficiency must be at least an order of magnitude greater than that which can be properly be assumed in the conventional approach.

Quasistellar Objects

The discovery of active galactic nuclei (AGN) in the 1960s in the hands of the radio astronomers was immediately followed by the discovery of the radio emitting quasi-stellar objects (QSOs), and Sandage and others showed that QSOs which were not radio emitters

were frequently present. Thus as Sandage somewhat rashly put it, a new constituent of the universe had been found.

How are these objects related to galaxies, and particularly to AGN, the distributed centers of creation as I have just described them?

The major property of QSOs which was totally unexpected is that they are highly compact and have the appearance of stars in our own galaxy, but have very large redshifts, as was first shown by Schmidt and Oke.

It was this latter property that led the community very early on to conclude that they must be very distant and very luminous. Thus it was assumed that they must be giving us information about the earlier state of the universe, and this meant that they could be used for cosmological investigation. But from the earliest days their properties were hard to understand in this way. Their apparent brightnesses are not smoothly correlated with their redshifts as is the case for normal galaxies. Thus if the redshifts are of cosmological origin there is a very wide scatter in the bolometric luminosities. Since the optical radiation is non-thermal this might well be the case.

Also the optical spectra of QSOs are dominated by strong, broad emission lines due to rapidly moving hot gas and thus they are very similar to the spectra of the nuclei of the class of AGN known as Seyfert nuclei (Seyfert 1943). Thus most astronomers immediately subscribed to the continuity argument first published by Krirtian (1965) who argued that at low redshifts it is easy to see the whole galaxy with its Seyfert nucleus, but as we study fainter and more distant objects with intrinsically brighter nuclei and larger redshifts the stars outside the nucleus are harder to detect and we only see the nucleus which we call a QSO.

When Kristian first showed the correlation based on very few objects it looked very good and this interpretation was widely accepted, even though he excluded from his plt the brightest QSO, 3C 273 which of course did not fit the correlation.

Later on many low redshift QSOs with $z \leq 0.2$ were observed with the Hubble telescope by Bahcall et al and were shown to lie in genuine spiral galaxies. There are also some bare QSOs. But the general problem remained. When low luminosity "fuzz" is seen around the image of a QSO is it always starlight, or is it high temperature gas with the same redshift? If it really is starlight and the continuity argument is correct, a spectrum should always show the normal stellar absorption spectrum with the same redshift as the emission-line QSO. In a number of the first cases studied for some of the bright QSOs, it was shown that the fuzz was not due to stars, but due to gas with narrow emission lines at the same redshift as the QSO. The fuzz was not starlight.

In only one of the early QSOs, 3C 48, was it shown that a galaxy was present at the same redshift. In this case the QSO is <u>not</u> symmetrically placed with respect to the QSO. As time has gone on there have been further elaborate studies of comparatively low redshift systems, and the view has grown up that the high redshift QSOs must all lie in elliptical galaxies. The only unambiguous way to test this is to study a sample in which the emission line redshift is <u>not</u> <u>known</u> and the redshift of the fuzz is determined first.

What is actually done is to do surface photometry; of the faint halo (fuzz) around to the QSO and then compare this with what you would expect to find in a giant elliptical galaxy. We still have no absorption line spectra of the fuzz around high redshift QSOs in which it can be shown that the two redshifts agree.

And this is one field in which no further progress will be made since everyone already <u>believes</u> that all QSOs lie in galaxies at the same redshift (it's in the textbooks, and you wouldn't get observing time to look, and after all for most people, AGN = QSO = AGN, by definition).

The problem gets even worse when we come to the redshifts. In the late 1960s several more observed properties of QSOs were found. First it was found that the optical and the radio flux was variable in time. This immediately sets a limit on the size of the emitting region. A more difficult problem immediately arose when it was realized that the non-thermal synchrotron radiation model would be self-quenching because the process would generate a photon energy density equal to the magnetic energy density. There are only two ways out of this. One is to argue that very large coherent relativistic motions are present so that very large values of $\gamma = (1 - v^2/c^2)^{-1}$ are involved.

The second is to argue that the variable sources are not the distances given by their redshifts - they are much closer, so the energy densities in the sources are much lower, and the contradiction is removed.

In 1966 when we brought up this dilemma (Hoyle, Burbidge, and Sargent 1966) Martin Rees (1966) and L. Woltjer (1966) immediately opted for and led the community to believe that highly relativistic motions were the answer. This was not surprising since the alternative explanation would mean that we had no explanation for the redshifts, and QSOs could not be used for cosmology.

Soon after this rapid angular motions began to be detected interferometrically in radio sources with both low and high redshifts. By now such motions have been found in many sources and we are told that for all high redshift objects superluminal motions are present, and they require large values of γ. However I have shown that in many of the sources there is a low redshift galaxy close to, or part of the high redshift variable radio source, and if

this is used to determine the distance of the object rather than the redshifts of the non-thermal sources the velocities are high but $\leq c$ (Burbidge, 2004) not highly relativistic i.e. the superluminal motions are an artifact of the redshift.

The most difficult problem involving the QSOs was brought to light by Arp in 1987 (see Arp 1987) and others (Burbidge, Burbidge, Solomon and Strittmatter, 1971; Arp, H.C., et al, 2002) who found statistical evidence suggesting that many high redshift QSOs lie so close to low redshift galaxies that they must be physically associated, so the QSO redshifts are not due to the expanding universe.

Arp's results are spectacular and are well known. His evidence and his persistence in putting it forward led his professional colleagues at Mount Wilson and Palomar in the early 1980's to having him removed from the telescopes, and he has lived and worked at the Max Planck Institute in Munich for the last 25 years.

This is one of the worst cases of discrimination involving scientific goals that I have ever seen. But it worked. The younger generation saw what happens if you don't follow the party line – no observing time, no staff or faculty positions, no financial support, no conference invitations. But to go back to redshifts.

For the last 25 years or more a small group involving particularly H.C. Arp, the Burbidges, the late Fred Hoyle, William Napier, and J.V. Narlikar, and a few others have shown that there is much observational evidence which shows that many bright QSOs with high redshifts are associated with low redshift, nearby galaxies many of which are highly active. One of the most recent and most spectacular discoveries was made by P. Gallianni, Margaret Burbidge, and others who found a QSO with a redshift $z = 2.11$ only 10ʺ from the center of a nearby galaxy NGC 7619 with $z = 0.001$ (Gallianni et al 2005). Since only a small number of the associations between high and low redshift objects show a luminous bridge e.g. (NGC 4319 and MK 205), (Arp, 1987); NGC 7503 and its companions, (Lopez-Corredoira & Gutierrez, 2007) the majority of the associations can only be tested by statistical techniques. Thus the results are always treated as controversial, largely because the referees of the papers and sometimes the editors don't want to believe the results. Despite prejudice quite a lot has been published, but then ignored.

By now there is general agreement that the observed effect is real, since statistical evidence of this clustering has been found even by groups who believe that all redshifts must be cosmological in origin. They try to argue that the effect is due to gravitational lensing by large amounts of dark matter which magnify the faint background QSOs lying close to the lower redshift galaxies, an ingenious argument first put forward by Canizares (1990). Of course the models don't really work, and as we shall discuss later there is no independent

evidence for the widespread existence of non-baryonic dark matter.

Dark Matter

The theory of stellar structure is one of the best understood branches of modern astrophysics and it is well established that dark matter is a natural end product of stellar evolution. Also stars with very small masses may be too faint to detect. Thus we expect that some dark matter will be present in the form of brown dwarfs, white dwarfs, neutron stars and black holes. Also diffuse matter in various forms may not be detectable through the emission or absorption of radiation.

Thus we can expect that dark matter is likely to be present in galaxies. Consequently it was not surprising when radio techniques and optical techniques led to the detection of the so-called flat rotation curves of spiral galaxies. These have been generally interpreted as meaning that in outer parts of flattened systems and in their halos there is much matter that cannot be seen but is exerting gravitational force.

Estimates of the amount of this dark matter have led to the idea that the total masses are much greater than those estimated from the visible stars, gas and dust, often by an order of magnitude or more.

The more general used of the virial theorem where it is <u>assumed</u> that all systems involving many galaxies are in equilibrium, leads to the general conclusion that there must be large amounts of dark matter in or between the galaxies in groups and clusters. In the hands of theoreticians this had led to the general belief that the larger the physical system is, the greater is the mass and the fraction of dark matter. This idea has been extended all the way from pairs of galaxies up to rich clusters. But the correlation has only been established by supposing that all of these systems are bound, i.e. the argument is circular. It has been supported by the discovery of large amounts of hot gas emitting X-rays in some rich clusters, and by the claim that evidence from gravitational lensing due to the presence of foreground clusters leads to the conclusion that large amount of unseen mass are always present. In support of this there clearly are many clusters where there is every indication that they are smooth and relaxed so that the virial argument is likely to be correct. But as is often the case in the band wagon approach it is now assumed that this is a general property of groups and clusters. Observationally it is true that in almost every case that the kinetic energy of the luminous systems appears to be much greater than the potential energy due to gravitational interaction. But this argument is taken to extreme lengths when pairs, or small interacting groups of galaxies are considered. For reasons not apparent to anyone outside the field, if two galaxies are seen to be interacting together it is always assumed that they are <u>coming</u> <u>together</u> or are in equilibrium. It is never assumed that they may be <u>coming</u>

apart. In the best cases it is possible to decide which, since if they are falling together tidal tails may be detectable. But in most cases, one cannot tell.

Why is the argument made this way? Because if they are coming together this is compatible with gravitational theory, but if they are coming apart we don't know why. Also in the standard galaxy formation scheme required in the big bang scenario, small galaxies are aggregated together to form more massive systems. In other words, while we might learn something new if we seriously considered that observations were telling us that in some cases galaxies are coming apart, for example perhaps galaxies beget galaxies, this possibility is ignored. Apparently because we don't want to seriously consider anything new.

In the 1960s Victor Ambartsumian studied very carefully many observations of clusters and groups, and made the radical suggestion that since many of the systems do not appear to be in equilibrium, perhaps they are not in equilibrium, and they may be coming apart. His arguments were ignored, for two reasons, both based on the belief that the hot big bang cosmology is correct. The first reason, as it was made by Jan Oort, is that if groups of galaxies are coming apart, we don't know where they are coming from, and since their lifetimes in the groups are short, they cannot have all been made in the early universe. The second simply as was stated above if they are exploding apart, we don't know why.

Neither of these objections is scientifically based, but as is the case in other aspects of cosmology, the fix is in, and belief in the use of the virial is overwhelming.

A second approach concerning the interactions between galaxies is the suggestion made by Milgrom (1983) that Newton's law needs to be modified for large distances. This idea was more recently put on a more firm theoretical basis by Beckenstein (2004).

With the use of this modification of Newton's law, it is possible to explain the flat rotation curves of spiral galaxies and some other phenomena, without requiring the presence of dark matter.

All of the observational evidence described so far is concerned with dark matter, and until theoretical cosmologists got into the act it was assumed without question that dark matter is made up of baryons, because this is all that we have direct scientific evidence for.

However, one of the major problems of cosmology is to understand the origin of galaxies. If the conventional big bang scheme is followed, the galaxies must have been formed early in the universe by the growth of density fluctuations (assumed to be present initially) in the hot expanding cloud. McCrea and others more than 60 years ago showed that such growth will not occur in a hot expanding cloud.

This could well be seen as a real objection to this cosmological model, but the general

view that has been developed is that since the model must be correct, the galaxies must have been formed. For this to occur it has to be <u>assumed</u> that there must be another component of mass present which can exert gravitational force but nothing else.

This has now been inserted into the theory and is dignified by the title "non- baryonic dark matter" (WIMPS). With this ingredient which must dominate, it is theoretically possible to simulate galaxy formation. Thus beautiful simulations of galaxy formation have been made by Simon White and Mike Norman and their groups, and others.

They make comparisons of their models which are all of dark galaxies, with what we see observationally in light, and it is claimed that the large scale structure seen in the visible galaxies is compatible with the models.

A second purely theoretical argument for the presence of non-baryonic dark matter is also completely based on the belief that there was a hot big bang. This comes from the fact that the amount of ordinary matter seen falls far short of the mass that must be present if primordial nucleosynthesis took place (Fukugita, Hogan, and Peebles 1998). Thus the shortfall is assumed to be made up of non-baryonic matter.

While many observations are now being directed towards the detection of dark matter, even if any of them is successful it will not be able to distinguish normal matter (which we know exits) from non-baryonic matter, for which there is not observational evidence at all.

Dark matter is certainly required in both the big bang and in the cyclic universe models. But in the cyclic universe model there is no reason to believe that anything other than normal matter is required to be present.

However, without the presence of non-baryonic matter the conventional cosmology fails.

If MOND turns out to be correct, and/or if in many situations the virial does not hold, the case for a very large amount of dark matter is severely weakened.

But the state of mind of the community is such that much effort is being exerted (and much money is spent) on looking for dark matter on the assumption that it must be there. Most of the observers no longer bother to distinguish between baryonic dark matter and non-baryonic dark matter, though one is real, and one may not be. And of course no one dares to make this argument to the funding agencies.

<u>Acceleration in the Universe</u>

Nearly 10 years ago, using supernovae of Type Ia as standard candles, Perlmutter, Riess et al (1999) reported that at redshifts in the range 0.5 to 1 the curvature in the Hubble relation suggested that the expansion is accelerating. Several reports since then

have supported these initial results (cf Riess et al). There are still a few very experienced observers, particularly Allan Sandage, who still doubt the reality of the effect. but if real acceleration is present, this agrees with the prediction made for the classical steady state model (cf Hoyle and Sandage 1956). It shows directly that matter creation is taking place long after any initial explosion may have occurred. However, the physicists who discovered this effect either were completely ignorant of the predictions of the past, or chose to ignore them. Thus they never mentioned the possibility, but instead the incorporated the results into the standard Friedmann model which they believe in, by bringing back to life the cosmical constant, which now claimed to be positive, (but according to the latest results has to vary with epoch) and arguing that they had discovered what they called "dark energy", which of course is another name for creation. Not surprisingly this result can be easily understood in the framework of the cyclic universe model (cf Viswakarma et al 2005), Narikar et al (2002) in which there is no big bang.

SUMMARY

In conclusion we summarize the strengths and weaknesses of the hot big bang model, and its alternatives.

(a) The major arguments in favor of the hot big bang model are that, on the surface at least, we can understand the expansion in terms of a Friedmann model, and if the parameters are chosen correctly we can explain out the details of the CMB as it is found at present. The very small structure in the radiation can be explained provided that it is supposed that the microwave field has interacted with the lumpy matter component early in the expansion, and that the matter had density fluctuations of unknown (probably quantum) origin. Moreover we can explain the abundances of the light isotopes made in the initial explosion.

However to explain the existence of galaxies, many unproven assumptions have to be made.

As is the case for all origin problems we must assume that there are initial density fluctuations. Early on it is necessary to invoke and inflationary phase for which we have no basic theory though it is an attractive idea. Also, in order to explain the abundance of the light isotopes and the flatness problem and so on we must invoke the presence of non-baryonic matter for which there is no direct evidence at all.

It is important to stress that this component must be dominant in forming galaxies, - without it galaxy formation cannot occur. Even then to make the large scale structure agree with observations other parameters must be used, including "biasing," and the falling together of small galaxies to form larger ones.

It is also necessary to ignore any of the evidence which points to radical events taking place in the nuclei of galaxies. Redshifts everywhere must be cosmological in origin and even effects like the Tifft effect, well-established by Gutherie and Napier (1996) and his colleagues showing that there is a small non-cosmological component in the redshifts or normal galaxies, must be ignored.

(b) The major evidence for a cyclic universe model is first that observations show that the major components of the universe are the galaxies which are condensed regions of matter (lumps). They are the primary energy sources, and all other constituents - other photon fields, and diffuser matter, etc., arise in them and are ejected from them.

The fact that the energy density in the CMB is in such good agreement with the amount of energy released in building the observed helium abundance through hydrogen burning (based simply on estimates of the masses of the galaxies and the observed distance scale) shows that the time scale for the process must be long and must be $> (H_o^{-1})$. Thus the observed expansion seen at this epoch does not have anything to do with the Friedmann solution to Einstein's equations. Instead the time scale leads directly to a cyclic universe model, originally described as the quasi-steady state model (QSSC)(Hoyle, ET AL 2000; Narlikar and Burbidge, 2007) which has a characteristic cycle time of $\approx 50 Gyr$ and an expansion timescale $\approx 10^{12} - 11^{13}$ years. In the hot big bang creation takes place once at t=0, but in the cyclic universe creation is taking place continuously.

Rather that being synthesized in a big bang, the light isotopes are made following creation in little big bangs in many galaxies over a long time scale. We have shown earlier that the helium can be made from hydrogen burning in galactic nuclei. The deuterium must be made in flares in stellar atmospheres.

The attraction of this aspect of the model is that it suggests that <u>all</u> of the elements are made in stars, and not just the heavier isotopes as was originally proposed by Cameron and B^2FH (Burbidge and Hoyle 1998). There is one other possibility for nucleosynthesis in galactic nuclei. As was originally realized by Wagoner, Fowler and Hoyle, and as described in Chapter 10 of Hoyle et al (2000), the physical conditions close to the condensed centers where little big bangs can occur, are $\rho \simeq 10^9 gm cm^{-3}$ and $T_9 = 10$. With a timescale of $\approx 1 - ^{-13}$ sec, and a baryon/photon ration ≈ 1 "local" primordial nucleosynthesis reactions can produce the observed abundances of the light isotopes.

In the cyclic universe we shall expect to see a build-up of dark baryonic matter, but there is no reason to invoke the presence of dark non-baryonic matter.

The main difficulty with this model is that we have no detailed understanding of the creation process, though the advantage here as compared with the big bang is that the

manifestations of creation in the form of active galaxies appear to be taking place all around us at every epoch.

A second difficulty, believed by many, is that we do not have the same detailed understanding of the energy distribution in the observed CMB as is claimed for the big bang (cf Spergel et al 2006). This is true, though some progress has been made (Narlikar et al 2003), but we believe that this is because to obtain the agreement between theory and observation in the conventional scheme many parameters which are really unknown, have to be chosen, and in addition, perhaps overwhelmingly, because hundreds of cosmologists are working on the big bang compared with a small handful who are looking at the alternatives.

(c) Other cosmological models are yet to be discovered. If it is ultimately confirmed, or even seriously believed, that Newton's law needs to be modified at large distances, as is suggested in MOND, basic changes will have to be made to what is being proposed in (a) and (b). And if we are forced to develop new physics to account for anomalous redshifts which I believe are real, this will undoubtedly tell us something fundamentally new about the origin of mass.

CONCLUSION

Cosmology is drive by observational discoveries, and after ninety years we are still a long way from a real understanding of the large scale structure of the universe. I believe that a major step backward was made in the 1960s when the leaders in the field decided that the basic problem had been solved, thus heavily biasing attitudes, outlook and funding in one direction only.

This meeting is dedicated to the memory of Denis Sciama. I knew him well in Cambridge and it is very good that we remember him here. Denis made major contributions, particularly in his encouragement and training of some of the leaders today. But to me Denis was unique in one way since he was the only leading cosmologist I have ever met who changed his mind Originally he passionately believed in the steady-state but later he was equally eloquent about the big bang.

Will such an event ever happen again?

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